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RECOVERY POTENTIAL ASSESSMENT OF SPOTTED GAR (*LEPISOSTEUS OCULATUS*) IN CANADA

Spotted Gar (Lepisosteus oculatus)
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Figure 1. Distribution of Spotted Gar in Canada.

Context :

*The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assessed the status of Spotted Gar (*Lepisosteus oculatus*) in April 1983. The assessment resulted in the designation of Spotted Gar as Special Concern. This status was re-assessed and confirmed in 1994. Spotted Gar status was re-assessed as Threatened in November 2000, which was confirmed in May 2005. This designation was assigned because Spotted Gar "...has a very limited range in Canada where it is only known from three coastal wetlands in Lake Erie. Although its distribution is likely limited by temperature, some of the shallow vegetated habitats that it requires for all life stages are subject to the impacts of siltation, dredging, filling, and aquatic vegetation removal and harbour improvements". Subsequent to the COSEWIC designation, Spotted Gar was included on Schedule 1 of the* Species at Risk Act *(SARA) when the Act was proclaimed in June 2003.*

A species Recovery Potential Assessment (RPA) process has been developed by Fisheries and Oceans Canada (DFO) Science to provide the information and scientific advice required to meet the various requirements of the SARA, such as the authorization to carry out activities that would otherwise violate the SARA as well as the development of recovery strategies. The scientific information also serves as advice to the Minister of DFO regarding the listing of the species under SARA and is used when analyzing the socio-economic impacts of adding the species to the list as well as during subsequent consultations, where applicable. This assessment considers the scientific data available with which to assess the recovery potential of Spotted Gar in Canada.

SUMMARY

- The current and historic Spotted Gar distribution is limited to seven distinct locations of the Great Lakes basin: Lake St. Clair, Point Pelee National Park, Rondeau Bay, Long Point Bay, Hamilton Harbour, East Lake and North Channel. Four of these locations are represented by

a single record (Lake St. Clair, Hamilton Habrour, East Lake and North Channel) (Figure 1). Current Spotted Gar population sizes are unknown.

- Adult Spotted Gar are typically found in shallow waters (Canadian records ranged from 0.23 to 2.6 m) of wetlands, marshes or flooded riparian areas. Dense vegetation appears to be a mandatory component of adult Spotted Gar preferred habitat. There are very limited data on habitat requirements for young-of-the-year (YOY) and juvenile Spotted Gar, necessitating the inference of these requirements from the adult life stage. Spawning occurs in the nearshore areas adjacent to preferred adult habitat.

- To achieve ~99% probability of persistence, given a 15% chance of catastrophic decline (50% decline in abundance), requires ~1400 adult Spotted Gar and at least 360 ha of suitable habitat. The definition of "extinct" has a large impact on Minimum Viable Population (MVP) size. If an extinction threshold of 10 females is considered, MVP becomes ~14000 adults requiring 3500 ha. Extinction risk is elevated exponentially when suitable habitat is at or below the minimum area for population viability.

- In the absence of additional harm or recovery effort, a population at 10% of MVP has a 95% chance of recovering within 45-66 years (depending on frequency of catastrophic events). Increasing survival of YOY and juveniles (the most efficient strategy) by just 10% improves recovery time to 23-29 years.

- The greatest threats to the survival and persistence of Spotted Gar in Canada are related to habitat modification and destruction, aquatic vegetation removal, increases in nutrient loading, and increases in turbidity and sediment loadings resulting from agricultural and urban development. Lesser threats that may be affecting the survival of Spotted Gar include the introduction of exotic species, and incidental harvest through the baitfish, recreational, and commercial fishing industries.

- Cumulative harm to annual survival of YOY and juvenile stages should not exceed 8%. Cumulative harm to adult survival or reproduction should not exceed 14 or 16%, respectively. Harm that affects multiple vital rates should be restricted further. For example, cumulative harm to survival of all life stages should not exceed 5%. Recovery time is delayed exponentially by any amount of harm above or below these thresholds.

- There remain numerous sources of uncertainty related to Spotted Gar population size, structure and the level of connectivity between populations. There is very little information available on preferred habitat of juvenile Spotted Gar. Numerous threats have been identified for the Spotted Gar, although the direct impact that these threats might have on Spotted Gar populations is currently unknown.

BACKGROUND

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) designated the Spotted Gar (*Lepisosteus oculatus*) population in Canada as Special Concern in April 1983. This status was re-assessed and confirmed in 1994. Spotted Gar status was re-assessed as Threatened in November 2000, which was confirmed in May 2005. Spotted Gar was subsequently included on Schedule 1 of the *Species at Risk Act* (SARA) when the Act was proclaimed in June 2003. When COSEWIC designates an aquatic species as Threatened or Endangered and the Governor in Council decides to list it, the Minister of Fisheries and Oceans Canada (DFO) is required by the SARA to undertake a number of actions. Many of these

actions require scientific information such as the current status of the population, the threats to its survival and recovery, and the feasibility of its recovery. This scientific advice is developed through a Recovery Potential Assessment (RPA). This allows for the consideration of peer-reviewed scientific analyses in subsequent SARA processes, including permitting on harm and recovery planning. This RPA focuses on Spotted Gar populations in Canada, and is a summary of a Canadian Science Advisory Secretariat peer-review meeting that occurred on June 23, 2010 in Burlington, Ontario. Two research documents, one providing background information on the species biology, habitat preferences, current status, threats and mitigations and alternatives (Bouvier and Mandrak 2010), and a second on allowable harm, population-based recovery targets, and habitat targets (Young and Koops 2010) provide an in-depth account of the information summarized below. Proceedings are also made available that document the activities and key discussions of the meeting (DFO 2010).

Species Description and Identification

The Spotted Gar (*Lepisosteus oculatus*) is very elongate with a long, slender, armoured body. The armoured body is covered in non-overlapping, bony ganoid scales making it easy to distinguish from other fish species. It is described as having a relatively broad snout with sharp teeth, and a short, deep caudal peduncle, followed by a rounded, heterocercal caudal fin. Body colouration can range from olive-green to brown above the lateral line with dark brown spots on the snout, head, body and fins.

The total length (TL) for this species typically ranges from 200-600 mm, while maximum age is thought to be 18 years. In Canada, the largest specimen recorded was 865 mm (TL) and was caught in Rondeau Bay in 2008. TL for Spotted Gar caught in Rondeau Bay from 2002-2009 ranged from 381 to 865 mm (n=929), while Spotted Gar caught in Point Pelee National Park from 2002-2009 (n=122) ranged in length from 133-718 mm.

Spotted Gar, a piscivorous ambush predator, is considered a key component to complex shallow wetland ecosystems. Spotted Gar may also feed on crayfishes and aquatic insects. A preliminary stomach content analysis was completed on 43 Spotted Gar captured from Rondeau Bay (TL ranged from 416-734 mm; B. Glass, unpubl. data). This study indicated that Spotted Gar diet consisted almost exclusively of fishes. Specifically, centrarchids, cyprinids and Central Mudminnow (*Umbra limi*) were the most abundant.

Spotted Gar is one of only two native gar species found in Canada, the other being Longnose Gar (*L. osseus*). It is important to note that there is a distributional overlap between these two species. Interestingly, Longnose Gar occur in all locations where Spotted Gar have been recorded, but the opposite does not hold true; Spotted Gar are absent from many suitable wetland habitats where Longnose Gar flourish. In comparison to Spotted Gar, Longnose Gar has a longer, narrower snout. A characteristic that may lead to confusion when comparing the two species is the presence of spots along the snout, head and body of the Longnose Gar. Both species are spotted and this should not be used as a characteristic in identification. Distinguishing between the species should be based on snout length and shape. The non-native Florida Gar (*L. platyrhincus*) has been recorded in the Great Lakes basin in what is presumed to be the result of aquarium releases. Florida Gar is very similar in appearance to Spotted Gar but there is one key characteristic that can separate these two species. The Florida Gar lacks the bony translucent plates (scales) that can be found on the isthmus (between the gill openings) of Spotted Gar.

ASSESSMENT

Current Species Status

Lake St. Clair

A single specimen was captured from Lake St. Clair in 1962. The narrative locality of this record indicated that it was captured 4 km west of the mouth of the Thames River. The south shore of Lake St. Clair has been recently sampled (2007-2008) by the Ontario Ministry of Natural Resources (OMNR) as part of their nearshore seining program. In addition, sampling was conducted in Lake St. Clair in 2002-2004 by DFO and in 2007 by Essex-Erie Conservation Authority. None of these studies yielded Spotted Gar captures.

Point Pelee National Park

A single historic Spotted Gar record was recorded from Point Pelee National Park. Although the original record indicated that the Spotted Gar was found in "Lake Erie at Point Pelee", it is thought that this record should occur within the park where habitat is more consistent with known Spotted Gar preferred habitat. Spotted Gar was not recorded again in Point Pelee National Park until 2002. Sampling with various gear types (fyke net, bag seine, trap net, Windermere trap, and boat electrofishing) from 2002-2009 yielded 122 Spotted Gar.

Rondeau Bay

The first record of Spotted Gar in Rondeau Bay dates back to 1947 when one individual was recorded from a commercial fisherman. From 1947 to 2000, only 10 additional Spotted Gar were recorded from this area. From 2002-2005, DFO conducted targeted sampling for Spotted Gar in Rondeau Bay that resulted in the capture of 50 additional individuals. The success in Spotted Gar capture led to a graduate student project that began in 2007 and is currently ongoing. Through this project, 477 individuals were captured via fyke net, and an additional 69 individuals were captured via boat electrofisher (B. Glass, University of Windsor, unpubl. data). Radio tracking of marked individuals in 2007 resulted in 212 marked locations. The success of this research program leads us to believe that a healthy Spotted Gar population is present in Rondeau Bay.

Lake Erie

Two historic Spotted Gar records were noted from Lake Erie proper (1925, 1938) that were recorded by commercial fisherman and listed as being captured at Merlin Road and Port Crewe. It is thought that these individuals may have been caught closer to the mouth of Rondeau Bay but the catch was not processed until much later, making the narrative locality inaccurate. For this reason they will not be discussed in terms of Population Status.

Long Point Bay

For the purposes of discussing Population Status, Long Point Bay will include Long Point Inner Bay, Big Creek Marsh and Long Point National Wildlife Area (NWA). A total of 14 Spotted Gar have been recorded from Long Point Bay; 11 from Long Point Inner Bay (one in 1947, 2003 and 2009, respectively; eight in 2010), one from the NWA (1984), and two from Big Creek Marsh (2004). The recent capture of eight Spotted Gar provides evidence that there is a reproducing population present at Long Point Bay (B. Glass, unpubl. data). Substantial sampling has occurred throughout Long Point Bay over the last ten years with minimal success in capturing Spotted Gar.

Hamilton Harbour

Although there have been reports of Spotted Gar in Hamilton Harbour in the past, these reports had not been substantiated with a voucher specimen until August 2010 when a single Spotted Gar (510 mm TL) was captured in a trapnet (OMNR, unpubl. data). This voucher specimen provides evidence that a reproducing population of Spotted Gar exists in Hamilton Harbour. Further sampling is necessary to confirm the presence of a population as well as to determine population size.

East Lake

The first, and only, Spotted Gar ever recorded from East Lake was captured by a commercial fisherman in 2007. Intensive sampling using gear known to be effective at capturing Spotted Gar was completed in East Lake in June and July 2008 to verify the presence of a reproducing population in this area (B. Glass, unpubl. data). No additional Spotted Gar were captured from this area during this targeted sampling. In addition, there has been extensive commercial hoop netting in East Lake and there has been only one recorded Spotted Gar capture, providing good evidence that a reproducing population does not currently exist for East Lake (J. Hoyle, OMNR, pers. comm.).

North Channel

A single Spotted Gar was captured from North Channel (north of Amherst Island, eastern Lake Ontario) in 1985, making this record the first verified record from the Lake Ontario drainage. In addition to extensive commercial fishing that is known to occur in this area, substantial sampling has been done in the area of the North Channel as part of the OMNR netting program; none of which have yielded the capture of Spotted Gar (J. Hoyle, OMNR, pers. comm.). The presence of a reproducing population is believed to be highly unlikely due to the disjunct location where this Spotted Gar was recorded, and the extensive sampling that has occurred in this area. It is speculated that this individual may be the result of an introduction.

Population Status

To assess the Population Status of Spotted Gar populations in Canada, each population was ranked in terms of its abundance (Relative Abundance Index) and trajectory (Population Trajectory). The level of certainty was associated with each assignment (1=quantitative analysis; 2=CPUE or standardized sampling; 3=expert opinion). The Relative Abundance Index and Population Trajectory values were combined in the Population Status matrix to determine the Population Status for each population. Each Population Status was subsequently ranked as Poor, Fair, Good, Unknown or Extirpated (Table 1). The Certainty assigned to each Population Status is reflective of the lowest level of certainty associated with either initial parameter. Refer to Bouvier and Mandrak (2010) for the complete methodology on Population Status assessment.

Table 1. *Population Status of all Spotted Gar populations in Canada, resulting from an analysis of both the Abundance Index and Population Trajectory. Certainty assigned to each Population Status is reflective of the lowest level of certainty associated with either initial parameter (Relative Abundance Index or Population Trajectory).*

Population	Population Status	Certainty
Lake St. Clair	Extirpated	3
Point Pelee	Fair	2
Rondeau Bay	Good	1
Long Point Bay	[redacted]	2
Hamilton Harbour	Unknown	3
East Lake	Unknown	2
North Channel	Unknown	3

Habitat Requirements

Spawning and Nursery

Spotted Gar are spring spawners, spawning in May and June when water temperature is between 21 and 26°C. Shoreward movement to spawning grounds was observed in Rondeau Bay when water temperature approached 18°C (B. Glass, pers. obs.). Spawning occurs in shallow (0-1 m water depth), heavily vegetated wetlands, marshes or flooded riparian areas. Spotted Gar were observed spawning in Rondeau Bay over vegetation beds comprised of milfoil (*Myriophyllum* sp.) and curly pondweed (*Potamogeton crispus*) (B. Glass, pers. comm.). Spawning generally involves several males and a single, larger, female. Sperm and eggs are deposited over weed beds and the adhesive eggs become fixed to the submergent macrophytes and debris where they remain until hatch (approximately one to two weeks). Nursery habitat is characterized by dense submergent and emergent vegetation.

Young-of-the-Year (YOY) and Juvenile

Young-of-the-year (YOY) remain in the spawning area until their yolk sac is fully absorbed, which occurs at approximately 17 mm TL or greater. Once absorbed, the YOY disperse and begin to feed. Limited data on both YOY and juvenile Spotted Gar habitat requirements necessitate the inference of these requirements from other, well-studied, life stages.

Adult

Adult Spotted Gar are generally found in quiet backwaters, or wetland areas. All adult Spotted Gar in Canada were caught in shallow water with water depth ranging between 0.23 and 2.6 m, with the exception of the Spotted Gar caught in the North Channel (eastern Lake Ontario) that was caught in water 7.5 m deep. Dense vegetation appears to be a mandatory component of adult Spotted Gar preferred habitat. Preferred substrate appears to be a mixture of silt, clay and sand. Water temperature at Canadian capture sites ranged from 11.4 to 31.3°C with the average being 22.6°C (± 0.19).

Preliminary results from a Spotted Gar tracking study that occurred in Rondeau Bay in 2007 indicated that of 212 tracking locations marked, 192 (or 92%) had macrophytes present, and that complex macrophytes dominated the samples. Collection sites were mainly composed of Eurasian milfoil, hornwort (*Ceratophyllum* spp.), stonewort (*Chara* spp.), various pondweed species (*Potamogeton* spp.) and water celery (*Vallisneria* spp.) (B. Glass, unpubl. data). Other commonly recorded species include water lily (*Nuphar* spp.), cattails (*Typha* spp.), and Canadian waterweed (*Elodea canadensis*). This dense vegetation requirement is thought to be

related to the foraging behaviour of the Spotted Gar in that the structurally complex habitat provides camouflage to the ambush predator and reduces the visibility of its potential prey.

Residence

Residence is defined in SARA as a, "dwelling-place, such as a den, nest or other similar area or place, that is occupied or habitually occupied by one or more individuals during all or part of their life cycles, including breeding, rearing, staging, wintering, feeding or hibernating". Residence is interpreted by DFO as being constructed by the organism. In the context of the above narrative description of habitat requirements during YOY, juvenile and adult life stages, Spotted Gar do not construct residences during their life cycle.

Recovery Targets

Recovery Targets and Times

We used demographic sustainability as a criterion to set recovery targets for the Spotted Gar. Demographic sustainability is related to the concept of a minimum viable population (MVP; Shaffer 1981), and was defined as the minimum adult population size that results in a desired probability of persistence over 100 years (approximately 20 generations). MVP targets were chosen to optimize the benefit of reduced extinction risk and the cost of increased recovery effort, and resulted in a persistence probability of approximately 99% over 100 years. Assuming that the chance of catastrophic decline was 0, 5, 10, or 15% per generation, simulations indicated that MVPs for a Canadian population of Spotted Gar are 82, 196, 528 or 1424 adults respectively. Populations were considered extinct at less than 2 adults (one male and one female). If the quasi-extinction threshold is defined as 20 adults, and the chance of catastrophe is 15% per generation, MVP increases from 1424 to 13840 adults. Thus, if the true extinction threshold is greater than 2 adults, larger recovery targets should be considered.

Under current conditions, and in the absence of recovery efforts, a Spotted Gar population that was at 10% of the above MVPs was predicted to take 45, 51, 57 or 66 years to reach a 95% probability of recovery, when probability of catastrophe was 0.0, 0.05, 0.1, or 0.15 respectively. For a probability of catastrophe of 0.15, the simulated recovery strategies improved recovery times from 66 years to between 18 and 46 years. The most effective simulated strategy was an improvement in early survival (from birth to maturity, Figure 2). Conversely, the time to recovery increased exponentially as harm was added to vital rates (Figure 3).

Minimum Area for Population Viability

Minimum area for population viability (MAPV) is a quantification of the amount of habitat required to support a viable population. Variables included in the MAPV assessment include MVP values and area required per individual (API values). API values were estimated from an allometry for river environments from freshwater fishes. With a target MVP of 1424 adults, under a 0.15 probability of catastrophe per generation, the MAPV is 360.8 hectares. If the extinction threshold is assumed to be 20 adults, the MVP increases to nearly 14 000 adults requiring ~3500 ha, which is larger than both Rondeau Bay and Point Pelee habitats. If available habitat does not meet the MAPV requirements, probability of extinction over 100 years increases exponentially, and time to recovery is likewise delayed (Figure 4).

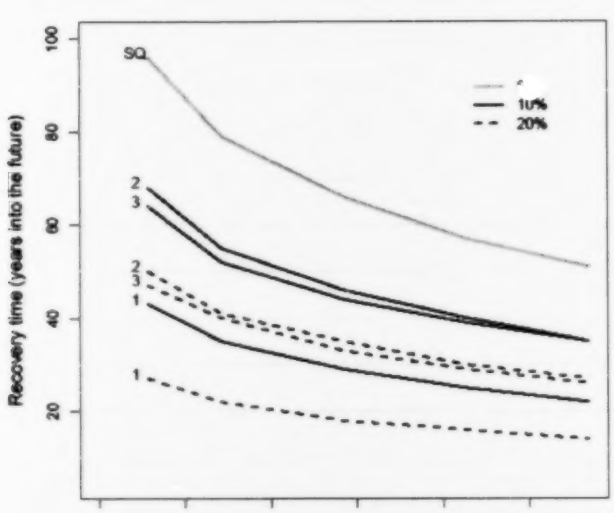

Figure 2. *Stochastic projections of mean Spotted Gar recovery times over a range of initial population sizes (number of adults) for 3 hypothetical recovery strategies (6 sub-strategies). Assumes 15% probability of catastrophe, and a recovery target of 1424 adults (initial populations range from 2-20% of this target). Grey line shows recovery times in the absence of mitigation or additional harm (status quo: SQ), and numbered lines correspond to strategies influencing early survival (1), adult survival (2), and fecundity (3).*

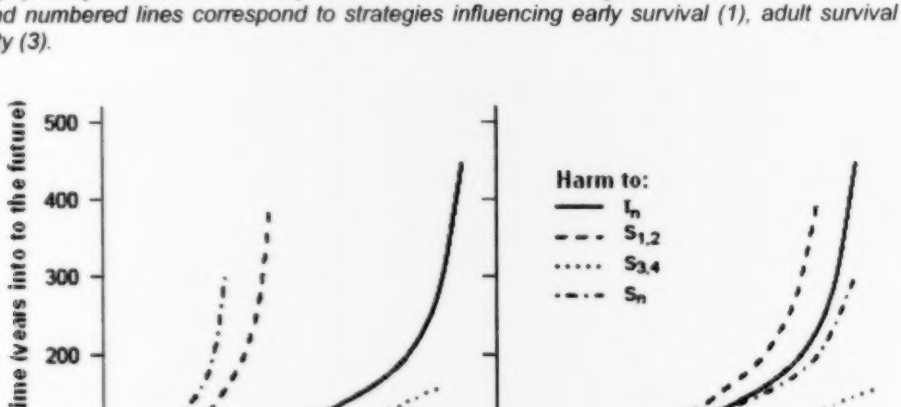

Figure 3. *Predicted change in the time to 95% chance of recovery of a Spotted Gar population that is experiencing increased harm to multiple vital rates: fecundity (f_n), early survival ($s_{1,2}$), adult survival ($s_{3,4}$), or all survival (s_n). Left panel: recovery times as a function of the proportion reduction to each set of vital rates. Right panel: recovery times as a function of scaled harm which ranges from status quo (0 harm) to maximum allowable harm.*

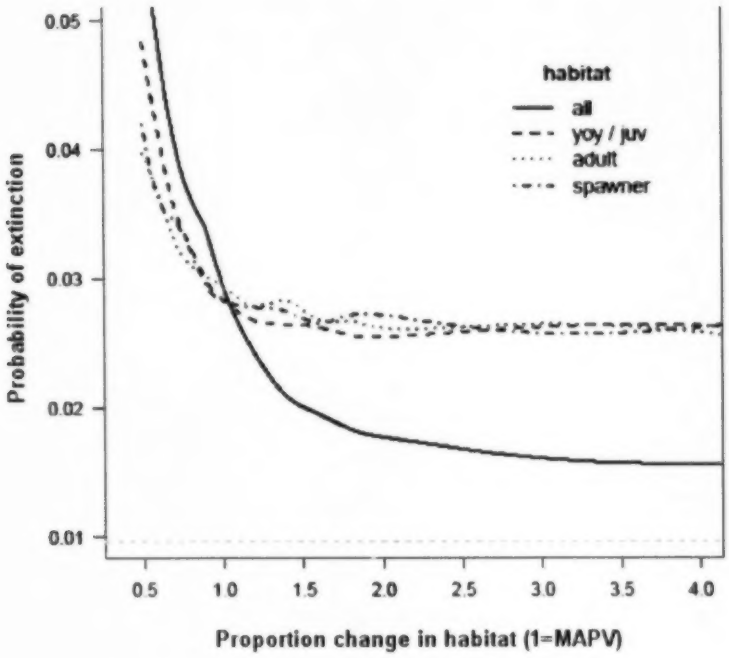

Figure 4. *Probability of extinction within 100 years of 10 simulated Spotted Gar populations at minimum viable population (MVP) size, and experiencing habitat based density dependence, as a function of habitat area. Simulations assume a 15% chance of catastrophe. X-axis indicates habitat size as a proportion of minimum area for population viability (MAPV). Each curve represents a different habitat unit. Dashed reference lines show MAPV (vertical) and the probability of extinction in the absence of habitat restrictions (horizontal).*

Threats to Survival and Recovery

A wide variety of threats negatively impact Spotted Gar across its range. Our knowledge of threat impacts on Spotted Gar populations is limited to general documentation, as there is a paucity of threat-specific cause and effect information in the literature. The greatest threats to the survival and persistence of Spotted Gar in Canada are related to habitat modification and destruction, aquatic vegetation removal, increases in nutrient loading, and increases in turbidity and sediment loadings resulting from agricultural and urban development. The presence of pristine, highly-vegetated systems in southwestern Ontario, where Spotted Gar thrive, is very limited. Locations where Spotted Gar currently exist are widely separated, potentially isolating these populations, and limiting the possibility of migration between locations. Lesser threats that may be affecting the survival of Spotted Gar include the introduction of exotic species, and incidental harvest through the baitfish, recreational, and commercial fishing industries, although the current knowledge on the level of impact that these threats may have on Spotted Gar is very limited. It is important to note that these threats may not always act independently on Spotted Gar populations; rather, one threat may directly affect another, or the interaction between two threats may introduce an interaction effect on Spotted Gar populations. It is quite difficult to quantify these interactions; therefore, each threat was assessed independently.

Threat Status

To assess the Threat Status of Spotted Gar populations in Canada, each threat was ranked in terms of the Threat Likelihood and Threat Impact on a population basis (see Bouvier and Mandrak 2010 for complete details on classification approach). Threat Impact categorization was location specific, in that impact categorization was assigned on a location-by-location basis. If no information was available on the Threat Impact at a specific location, a precautionary approach was used - the highest level of impact from all sites was applied. The Threat Likelihood and Threat Impact for each population were subsequently combined in the Threat Status Matrix resulting in the final Threat Status for each location (Table 2). Certainty has been classified for Threat Impact and is based on: 1= causative studies; 2=correlative studies; and, 3=expert opinion.

Table 2. *Threat Status for all Spotted Gar populations, resulting from an analysis of both the Threat Likelihood and Threat Impact. The number in brackets refers to the level of certainty assigned to each Threat Status, which relates to the level of certainty associated with Threat Impact. Certainty has been classified as: 1= causative studies; 2=correlative studies; and 3=expert opinion. Gray cells indicate that the threat is not applicable to the population due to the nature of the aquatic system where the population is located. Clear cells do not necessarily represent a lack of a relationship between a population and a threat; rather, they indicate that either the Threat Likelihood or Threat Impact was Unknown.*

	Lake Erie drainage			Lake St. Clair drainage	Lake Ontario drainage	
Threat	**Point Pelee**	**Rondeau Bay**	**Long Point**	**Lake St. Clair**	**Hamilton Harbour**	**East Lake**
Habitat modifications			Low (3)		Low (3)	Low (3)
Aquatic vegetation removal						
Mechanical	Low (3)		Low (3)	Unknown (3)		Low (3)
Chemical			Low (3)	Low (3)		
Turbidity and sediment loading	Low (3)			Medium (3)	Medium (3)	Unknown (3)
Nutrient loading	Low (3)			Low (3)	Low (3)	Unknown (3)
Exotic species	Medium (3)	Medium (3)	Medium (3)	Medium (3)	Medium (3)	Medium (3)
Incidental harvest	Low (3)	Low (3)	Low (2)	Low (3)	Low (3)	Low (3)

N.B. The Threat Status represents a combination of the current Threat Impact and Threat Likelihood at a location. It does not reflect the potential impact a threat might have on a population if it was allowed to occur in the future.

Allowable Harm

Allowable harm was assessed in a demographic framework following Vélez-Espino and Koops (2009). The assessment involves perturbation analyses of population projection matrices, and includes a stochastic element. Outputs of the analyses include calculation of a population growth rate and its sensitivity to changes in vital rates. See Young and Koops (2010) for complete details of the model and results. Modelling indicated that population growth of the Spotted Gar is most sensitive to perturbations of annual survival in early life (s_1), and is also sensitive to survival and fertility (f_1) of early adults (Figure 5). Uncertainty in sensitivity is driven primarily by uncertainty in the estimate of juvenile survival. Maximum allowable harm should be limited to 15% and 19% for survival of juveniles or age-0 individuals respectively, and 21% or

22% for early adult fertility and survival, respectively. Simultaneous impacts on overall survival or fertility should not exceed 5% or 16%, respectively. If human activities are such that harm exceeds just one of these thresholds, the future survival of individual populations is likely to be compromised.

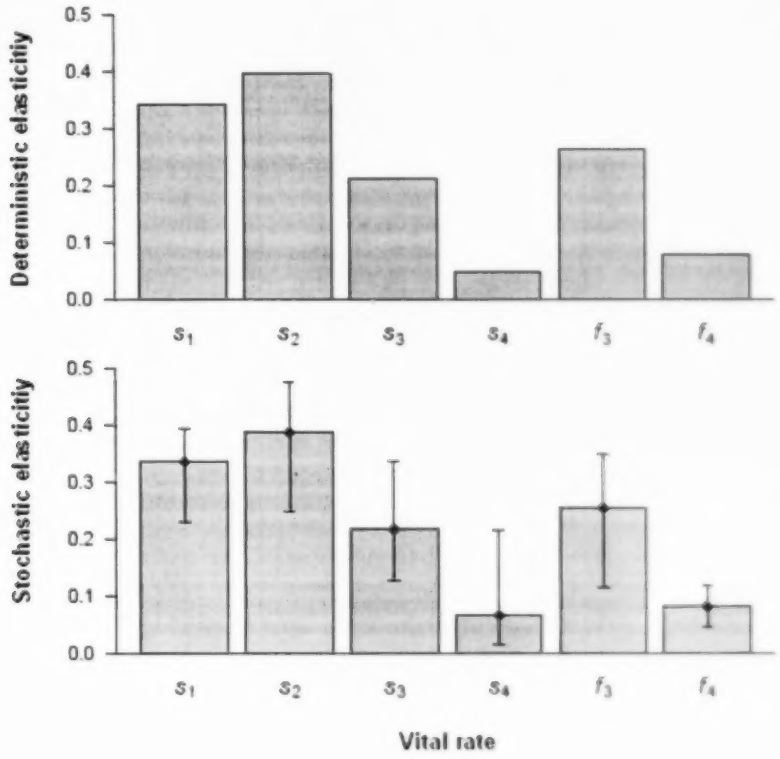

Figure 5. *Results of the deterministic and stochastic perturbation analysis showing elasticities (ε_i) of the vital rates: annual survival probability of stage i (s_i) and fertility of stage i (f_i). Stochastic results include associated bootstrapped 95% confidence intervals.*

Summary of Science Advice on Allowable Harm

- When population trajectory is declining there is no scope for allowable harm
- When population trajectory is unknown the scope for allowable harm can only be assessed once population data are collected
- Scientific research to advance the knowledge of population data should be allowed
- In the absence of population abundance estimates, no harm should be allowed to survival of YOY and juveniles
- Modeling indicates that minimal additional cumulative harm is allowable on survival and reproduction of adults aged 6 and under
- Survival and reproduction of older adults is less susceptible to harm
- If population abundance estimates exceed MVP, cumulative allowable harm might be allowed to the level identified in the allowable harm modeling

Mitigations and Alternatives

Numerous threats affecting Spotted Gar populations are related to habitat loss or degradation. Habitat-related threats to Spotted Gar have been linked to the Pathways of Effects developed by DFO Fish Habitat Management (FHM) (Table 3). DFO FHM has developed guidance on generic mitigation measures for 19 Pathways of Effects for the protection of aquatic species at risk in the Ontario Great Lakes Area (Coker et al. 2010). This guidance should be referred to when considering mitigation and alternative strategies. Additional mitigation and alternative measures, specific to the Spotted Gar, related to the introduction of exotic species and incidental harvest through the baitfish, recreational, and commercial fishing industries are listed below.

Table 3. *Threats to Spotted Gar populations and the Pathways of Effect associated with each threat. 1 - Vegetation clearing; 2 – Grading; 3 – Excavation; 4 – Use of explosives; 5 – Use of industrial equipment; 6 – Cleaning or maintenance of bridges or other structures; 7 – Riparian planting; 8 – Streamside livestock grazing; 9 – Marine seismic surveys; 10 – Placement of material or structures in water; 11 – Dredging; 12 – Water extraction; 13 – Organic debris management; 14 – Wastewater management; 15 – Addition or removal of aquatic vegetation; 16 – Change in timing, duration and frequency of flow; 17 – Fish passage issues; 18 – Structure removal; 19 – Placement of marine finfish aquaculture site.*

Threat	Pathways
Habitat loss and degradation	1, 2, 3, 4, 5, 7, 8, 10, 11, 13, 14, 15, 16, 18
Aquatic vegetation removal	10, 11, 15
Turbidity and sediment loading	1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13, 15, 16, 18
Nutrient loading	1, 4, 7, 8, 11, 12, 13, 14, 15, 16

Exotic species

Common Carp, Eurasian milfoil, Florida Gar and Round Goby introduction and establishment could have negative effects on Spotted Gar populations.

Mitigation

- Removal/control of non-native species from areas known to be inhabited by Spotted Gar.
- Establish "Safe Harbours" in areas known to have suitable Spotted Gar habitat. Safe Harbours work to minimize the impact or prevent the introduction of exotic species through best management practices.
- Watershed monitoring for early detection of exotic species that may negatively affect Spotted Gar populations, or negatively affect Spotted Gar preferred habitat. If exotics are detected, implement a rapid response plan to eradicate or control the newly discovered species.
- Introduction of a public awareness campaign.

Alternatives

- Unauthorized introductions
    - There are no alternatives for unauthorized introduction because unauthorized introductions should not occur.
- Authorized introductions
    - Do not carry out introduction where Spotted Gar is known to exist.

Incidental Harvest

Incidental harvest through the baitfish, recreational, and commercial fishing industries was recognized as a potential threat.

Mitigation

- Provide information and education to commercial fishermen, bait harvesters and recreational anglers on Spotted Gar, and request the voluntary avoidance of occupied Spotted Gar areas.
- Immediate release of Spotted Gar if incidentally caught.
- Introduction of timing windows so commercial and recreational fishing does not occur during Spotted Gar spawning season.

Alternatives

- Prohibition on the commercial and recreational fishing industry in areas where Spotted Gar is known to exist.

Sources of Uncertainty

Despite concerted efforts to increase our knowledge of Spotted Gar in Canada, there are still areas of uncertainty related to population structure, Spotted Gar life history, and to the factors that are limiting their existence.

Only a single record exists for four locations where Spotted Gar have been caught (Lake St. Clair, Hamilton Harbour, East Lake and North Channel), suggesting that our knowledge on its current distribution is incomplete. Increased sampling effort in these areas is needed to determine if reproducing populations exist and, if so, the size of the current populations. Although eight individuals have recently been captured at Long Point Bay, there remains some uncertainty as to whether or not a reproducing population exists for this location. Further investigation at Long Point Bay is required to confirm the presence of a reproducing population. Spotted Gar populations that were assigned low certainty in the population status analysis should be considered priority when considering additional field sampling. These baseline data are required to monitor trends in Spotted Gar distribution and abundance as well as the success of any recovery measures. There is a need to assess genetic variation across all Spotted Gar populations in Canada to determine population structure and the level of connectivity between populations.

There is a need to identify habitat requirements for each life stage. Areas of particular uncertainty are related to the juvenile life stage. Very little information is available regarding the preferred habitat of juvenile Spotted Gar necessitating the inference of these requirements from other life stages. There is a need to determine the seasonal habitat requirements for adult Spotted Gar, and whether or not these needs vary by season.

Numerous threats have been identified for Spotted Gar populations in Canada, although the direct impact that these threats might have is currently unknown. There is a need for more causative studies to evaluate the impact of each threat on each extant Spotted Gar population with greater certainty. In the literature, the threat impacts are generally discussed at a broad level (i.e., fish assemblage level). It is important to further our knowledge on threat likelihood and impact at the species level. The effect of vegetation control is currently unknown for Spotted Gar. There is a need to investigate the effects of vegetation removal through both mechanical and chemical removal and what effects chemical application might have on the reproduction and development of Spotted Gar. There is a need to determine threshold levels for

water quality parameters, and to identify point sources of nutrient and sediment inputs and their relative effects on Spotted Gar survival.

Many of the variables required to inform the population modelling efforts are currently unknown, or are only known for non-Canadian populations. Uncertainty in parameter estimates has resulted in large uncertainty in the population growth rates. Studies should focus on acquiring additional information on fecundity of Canadian populations, and annual survival rates of immature individuals. Estimates of population growth rates and true extinction thresholds are also needed. Finally, the frequency and magnitude of catastrophic events are unknown.

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